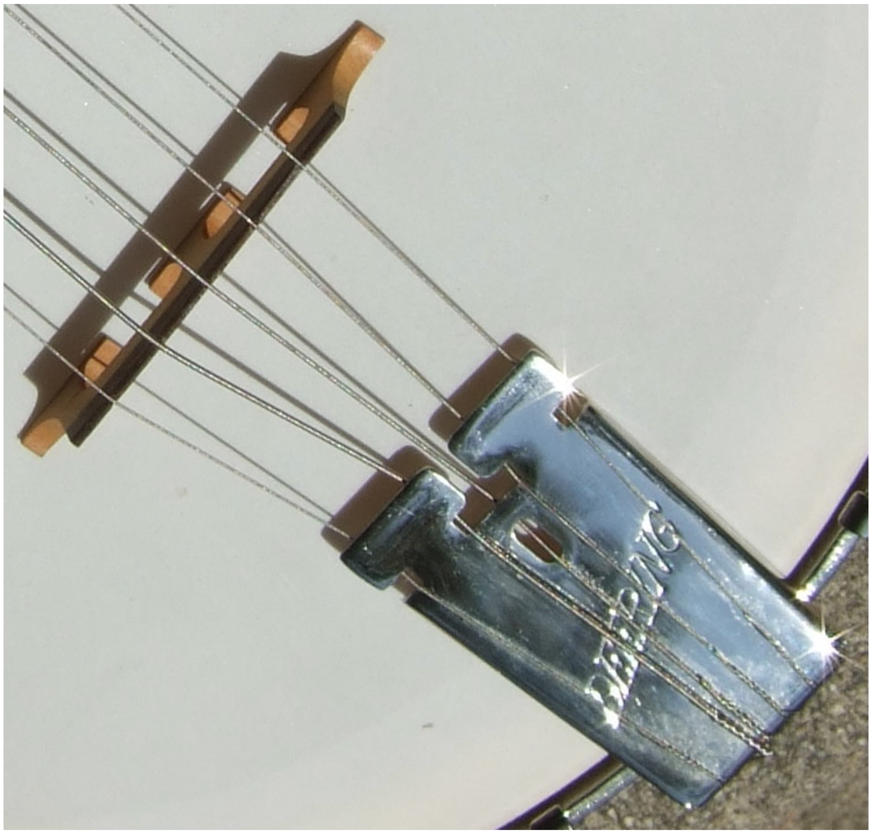

Very Heavy Banjo Strings

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Basic string physics is simple. Rather, this is a reminder that, for the price of a new set of strings, one can create a different instrument. In particular, for a given scale length, the tension can be maintained with heavier strings by tuning lower. An extreme case is illustrated here: replace original light gauge strings with Gold Tone's "baritone" strings, which are their choice for their "Missing Link" banjo. On the particular instrument used for this demo, tuning about an octave low preserves the original total string tension. That puts the instrument in the league of the baritone and cello banjos.

This is a case of where a difference in degree becomes a difference in kind.

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I. INTRODUCTION

During the banjo craze that gripped America and Britain in the decades just before and after 1900, banjos came in all sizes. While no style ever completely disappeared and individual builders continue to make instruments to their fancy, large manufacturers consolidated their production. The cello banjo (tuned an octave low) may have been the last large one to disappear, its role in dance and jazz bands made obsolete by electrical amplification.

According to Marcy Marxer, Mike Seeger loaned her an old cello banjo that had long lain unplayed. Her performances with Cathy Fink caught the attention of Wayne Rogers of Gold Tone, who then worked with Marxer to bring an instrument to market. One of many enthusiasts was Béla Fleck. After a while, Fleck suggested to Gold Tone that he work with them to produce something in between that cello and the instrument he normally played — hence the name, Missing Link. Billy Strings is a huge Missing Link fan as well.

This note presents the results of putting the string set sold for the baritone or Missing Link on a light-weight banjo. I chose to try a commercially packaged set because the work had already been done to have gauges whose tensions fit playing in standard tunings. The result was quite playable without any further modifications, tuning about an octave low to match the original total string tension. Minor issues (discussed herein) explain why the mass-produced instrument differs in some small details.

II. OUTLINE

With no attempt to compare to mathematical modeling, the recording effort was fast and dirty. The goal is just to give a qualitative impression.

This note is organized as follows. Section §III has short played samples of the banjo with original and with heavy strings. The particular instrument is described in section §IV. Spectrograms of single string plucks in section §V reflect some of the relevant physics and highlight aspects of how the change with the heavier strings is not just pitch but also timbre. Some peculiarities just are what they are. But head tension is discussed as one aspect in which the "converted" banjo can be setup to do a better job of matching the sound of the ready-mades. Section §VI briefly notes why Gold Tone's Missing Link has a wider neck and bigger frets.

III. COMPARISONS OF PLAYED SAMPLES

For bare finger picking on the original light strings, click here or go to https://www.its.caltech.edu/~politzer/heavy-strings/original-Frankie.mp3 . And compare to the same bit played on the heavy strings: click here or go to https://www.its.caltech.edu/~politzer/heavy-strings/heavy-Frankie.mp3.

And this is a frailed selection, played on the original and then heavy strings:
click here or go to https://www.its.caltech.edu/~politzer/heavy-strings/original-Roscoe.mp3.
click here or go to https://www.its.caltech.edu/~politzer/heavy-strings/heavy-Roscoe.mp3.

A final comparison is between head tensions, picked in both cases on the heavy strings. The first is with the head at 91 on a DrumDial. The second is at 87, chosen to mimic the larger heads of the Gold Tone baritone and cello banjos. At 91DD: click here or go to https://www.its.caltech.edu/~politzer/heavy-strings/heavy-starfish.mp3. And at 87DD: click here or go to https://www.its.caltech.edu/~politzer/heavy-strings/heavy-87DD-starfish.mp3.

NOTE: The 87DD version sounds much better to me, but I cannot guarantee that the difference is solely attributable to the lowered head tension. The recording protocols were nowhere as careful as was my wont. Nevertheless, the motivation is sound, and the single string pluck spectrograms in section § V support the idea. In fact, the sound of the 4^{th} *string pluck sounds "smoother" (?) with 87 DD instead of 91DD. If you try this for yourself, it's easy enough to loosen your head and listen for the changes.*

A played sample, tuned up a whole step to low aDADE with the head at 87 DD is linked in section §VII.

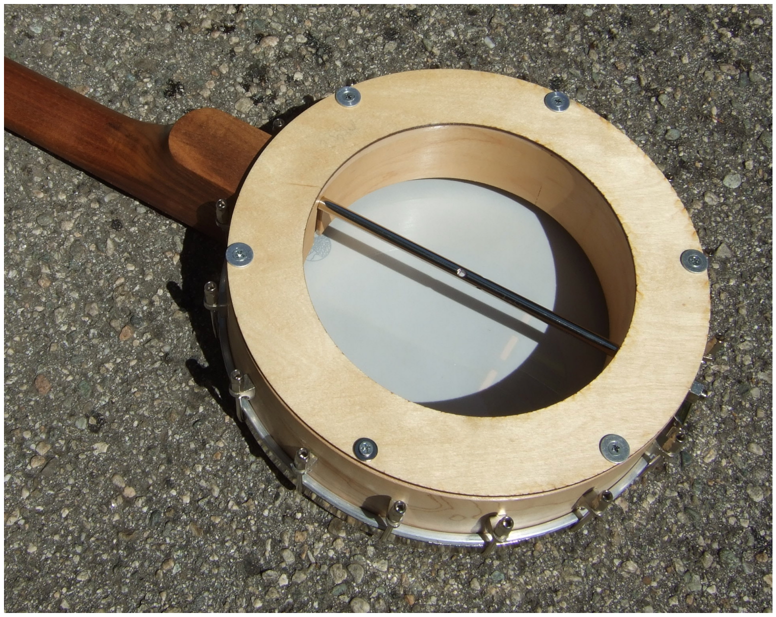
IV. THE PARTICULAR BANJO USED HERE

The banjo used in those recordings was one of my retired research-grade Goodtimes. Note that **any** banjo would do. Three aspects set it apart from a factory standard issue. The neck is walnut (although cut out on the Goodtime CNC neck machine). The head has a double thickness for about an inch around the edge, akin to the Remo Powerstroke heads or the Indian tabla.[1] That's visible in the photos. It preferentially reduces the sound radiation from the highest frequency head modes, resulting in less "ping" sound from a head tap. I regard it as a poor man's alternative to the Dobson or Bacon tone ring. Those certainly stiffen the rim, but, more significantly, they similarly reduce the high frequency sound radiation from near the rim. The banjo also has an internal resonator.[2] That adds a much lower resonance to the pot air modes, thereby enhancing the sound production of the lowest string modes.

The slots in the standard Goodtime nut are actually quite wide. Only the new 4^{th} string rides a bit high. But, in fact, there was no buzzing or jumping of strings when the instrument was played without nut or bridge modification. (Of course, in the long run, one might want to get better fits — or not, as the case may be.)

A. the strings and choice of tuning

The original light strings were Deering Goodtime factory standards: 10,11,13,21w,10. The baritone strings are 18,22,30,40,18, all wound. The relative weights of solid steel strings can be deduced from their diameters. With wound strings, it depends on their construction. So, a safe bet is to go to a string tension calculator, such as provided on-line by D'Addario



— https://www.daddario.com/string-tension-pro. The neck of the banjo I used is a single piece for the length of the neck, and it has no truss rod. This design has stood up well since its inception in 1998. However, it just makes good sense to not ask it to hold up under higher tension.

According to D'Addario, the factory-supplied Goodtime strings in G tuning produce a total tension of 61.9 lbs. The Gold Tone baritone strings tuned down one octave produce 50.5 lbs in double-C tuning (my choice). Raising that by a whole step produces 63.6 lbs. The recordings in this note are all with tuning down a full octave. That was my guess before consulting the string tension calculator. For future enjoyment, unless otherwise required, I'll tune it up that one whole note to double-D. The sound is just a bit cleaner. (Listen to the link in section §VII.) If your banjo has a truss rod and/or you normally use strings heavier than the light gauge ones compared here, you certainly could tune higher (where the sound is a bit smoother).

According to Gold Tone's catalog, the actual Missing Link has a wider neck than their standard 5-string banjos. That's discussed in section §VI. Of course, it also has a truss rod. So, they're happy to tune it down only half an octave from standard — and leave the octave interval to their cello banjo.

V. SINGLE STRING PLUCK SPECTROGRAMS

The following single string plucks were performed at the 14th fret, all strings open, with a wire break, a technique I used many times before. The results are highly reproducible from pluck to pluck and can be performed in another situation (e.g., here with other strings) at the same location and with the same force.

The sound of two representative plucks on the 1st strings, first with the original strings and head at 91DD, and second with the heavy strings and head lowered to 87DD (explained below), are here or go to https://www.its.caltech.edu/~politzer/heavy-strings/1st-comparison.mp3. Spectrograms of those recordings are in FIG. 1.

Two characteristics of all drum-headed string instruments are evident in both spectrograms. Compared to wood-topped instruments, the power in increasingly higher harmonics falls off relatively slowly. And inharmonic partials are produced by the strings that are not plucked. Those are identified in ref. [4] as the source of banjo ring.

But there are at least three qualitative ways in which the heavier string sound is different — beside all harmonics being at half the light gauge string frequencies. 1) While the lowest (i.e., fundamental) light gauge harmonic is far and away the strongest (perhaps not a surprise for a 14th fret pluck), the heavy string puts lots of power into the second through fifth harmonics. We hear the proper pitch courtesy of the phenomenon known as the missing fundamental. (Actually, we can hear a distinct pitch defined by equally spaced partials even if the set starts at a frequency much higher than the discerned pitch.[3]) 2) Many harmonics exhibit beats in time – far more than occurs with the light strings. And 3) the heavy string exhibits much stronger components of pitch glide. This is most evident in the higher harmonics, whose pitches drop as a function of time. This is simple physics and a consequence of string stiffness.[6] The net effect of the pitch glides is heard in the attack sound of the picked string. Wood-topped guitars employ the same kind of wound steel strings, but the glide sound is not as prominent because high string harmonics do not produce nearly as much sound as they do on banjos.

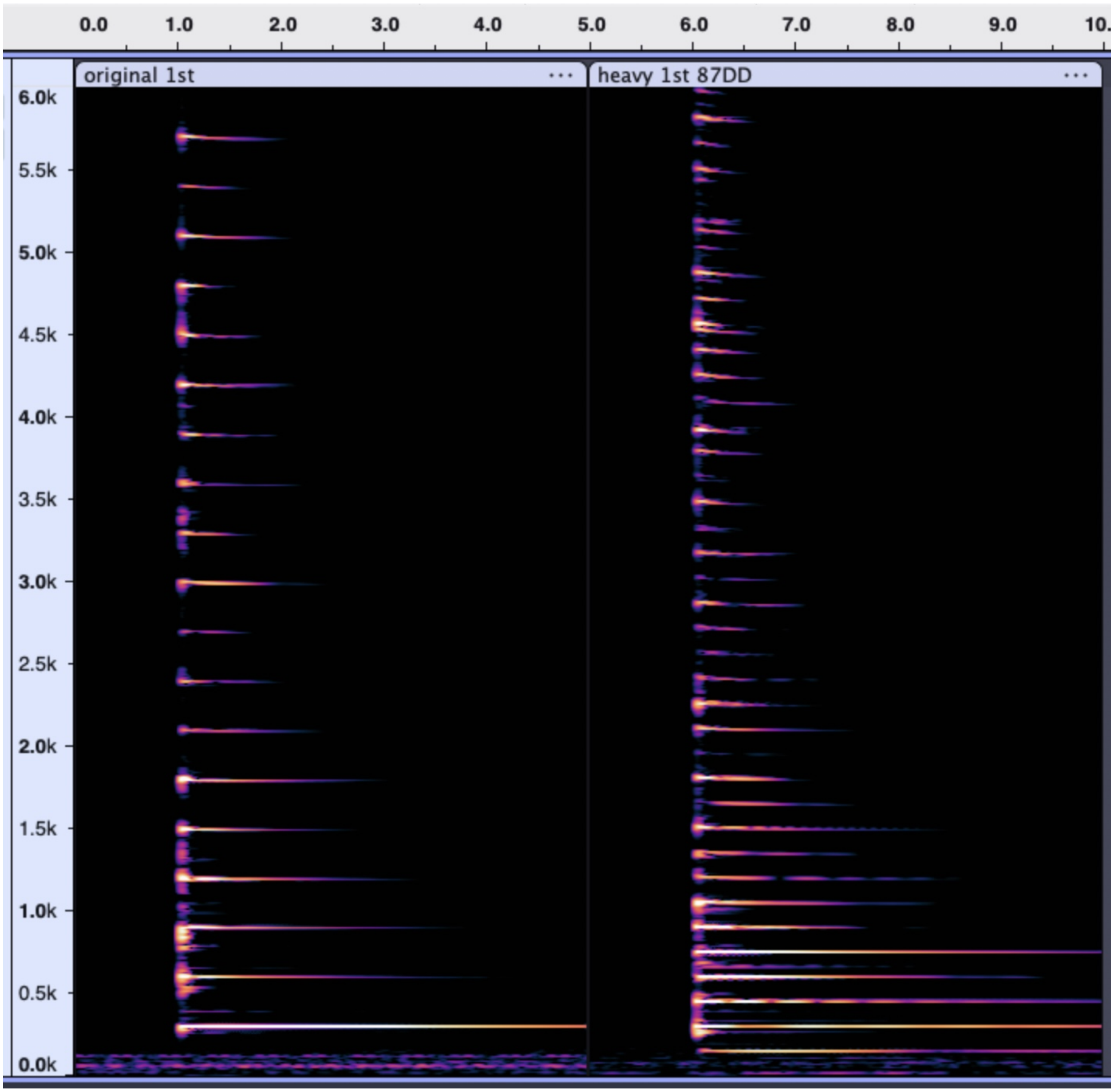


FIG. 1. 1st string plucks at the 14th fret with strings open

The sound of three representative plucks on the 4th strings, first with the original strings and head at 91DD, second with the heavy strings and head also at 91DD, and third with the heavy strings and head lowered to 87DD, are here or go to https://www.its.caltech.edu/~politzer/heavy-strings/4th-comparison.mp3. Spectrograms of those recordings are in FIG. 2.

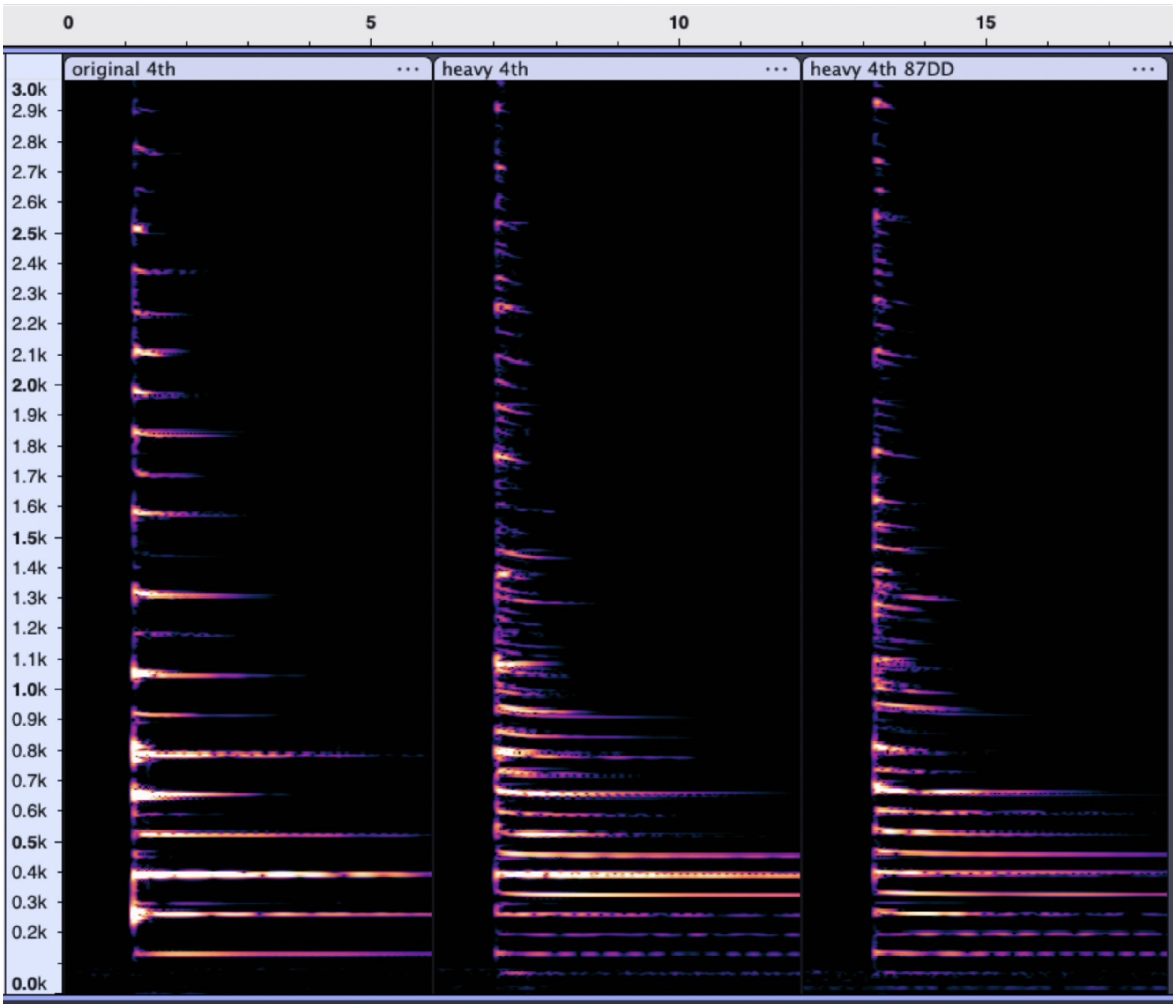


FIG. 2. 4th string plucks at the 14th fret with strings open

Even with light gauge strings, the pitch of the open 4th string is below the lowest resonance of the head. That is why the strongest harmonic is the third one.

With the head still tensioned to the original 91DD, the sound of the heavy 4th string, tuned an octave below what it was for the light strings, is strongest at the *same* frequency as it was with the light strings. The fundamental frequency is barely visible in the spectrogram. Nevertheless, we hear the proper pitch because of the equal spacing of the harmonics.

The timber of that 4th string pluck is strongly impacted by the evident early-time pitch glide, by the prominent beating, and by the strength of the inharmonic partials. Each of these effects are more dramatic than they were with the light gauge 4th string.

A. modifying the head tension

When the head tension is lowered from 91DD to 87DD, we see the same harmonic frequencies, similar pitch glide, and similar beating. However, the frequency centroid of radiated sound power shifts down somewhat, at least for the lowest nine harmonics.

The motivation for trying this head tension modification and the particular choice of 87 is as follows. The Gold Tone Missing Link and cello banjos have head diameters of 12″ and 14″, respectively, while the Goodtime is 11″. When comparing the various instruments, if the heads are all of the same mass density per unit area (e.g., all Remo top-frosted) and they are all at the same tension, the head modal frequencies will all decrease by a common factor of $1/D$, where D is the head diameter. If one includes the possibility of varying the head tension, T, then the set of head modal frequencies scales like $T^{\frac{1}{2}}/D$. In particular, choosing a T to reproduce the value of $T^{\frac{1}{2}}/D$ for a different D will ideally produce the same head modal frequencies.

Banjo pickers and builders don't normally consider numerical values for the actual head tension. Some years ago, I requested the relevant information from the makers of the commercial DrumDial. The dots in FIG. 3 are the data they sent back. The smooth line is my own interpolation/extrapolation. The only unequivocal input into that line is that it must go to infinity as the DrumDial reading goes to 100. (The value at 90DD agreed reasonably with a physics-based determination that used the weight of the mylar.[5]) That conversion graph allowed me to use $T^{\frac{1}{2}}/D$ to get head mode frequencies closer to what I presume are recommended for the Missing Link. The efficiency of sound radiation is actually a complex subject[5]. So, scaling the head tension using $T^{\frac{1}{2}}/D$ does not tell the whole story — but it's a reasonable first approximation for getting a similar head response to the strings..

VI. GOLD TONE'S MISSING LINK

When playing my new low-pitched banjo, I noticed that it took extra care to not get buzz sounds from fingers touching neighboring strings when those strings were fretted. Some of that is evident in the recordings. Gold Tone's catalog notes that the Missing Link has a

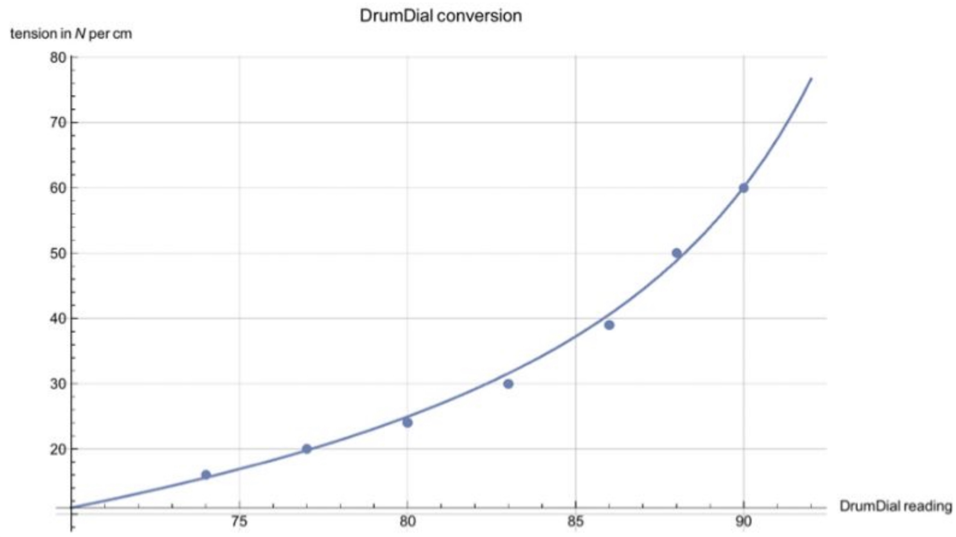


FIG. 3. Points are data provided by the maker of DrumDial; the line is plausible interpolation/extrapolation.

wider neck and fatter frets than standard. In collaborating on design, Béla Fleck certainly played prototypes and must have encountered the same issue — albeit to a lesser extent. Wider neck and fatter frets ameliorate this issue.

VII. CONCLUSION

For the price of a new set of strings, you can have a new instrument!

Here is a final sound sample[7] with a heavier bridge, the head at 87DD, and tuned to low double-D, i.e., aDADE: https://www.its.caltech.edu/~politzer/heavy-strings/banjo-song-87DD-double-D.mp3

Oh, why not one more? A bit more cheerful: https://www.its.caltech.edu/~politzer/heavy-strings/heavy-double-D-87DD-Blue.mp3

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[1] *DIY Mylar Flange for a More Mellow Banjo Head*, D. Politzer, HDP: 17 - 01http://www.its.caltech.edu/~politzer – March 2017

[2] *Physics of the Bacon Internal Resonator Banjo*, D. Politzer, HDP: 16 - 02, http://www.its.caltech.edu/~politzer – JUNE 2016

[3] *Pickers' Guide to* Acoustics of the Banjo, D. Politzer, J. Woodhouse, and H. Mansour, HDP: 21 – 01, http://www.its.caltech.edu/~politzer – APRIL 2021; see the addendum starting on p. 17.

[4] *Inharmonic Partials and Banjo Ring*, D. Politzer, HDP: 24 - 6, http://www.its.caltech.edu/~politzer – MARCH 2024.

[5] *Pickers' Guide to* Acoustics of the Banjo, D. Politzer, J. Woodhouse, and H. Mansour, HDP: 21 – 01, http://www.its.caltech.edu/~politzer – APRIL 2021; a longer, more technical exposition is available as open-access as *Acoustics of the Banjo: measurements and sound synthesis & theoretical and numerical modelling*, J. Woodhouse, D. Politzer, and H. Mansour, Acta Acustica, **5**, 15 and 16 (2021) https://doi.org/10.1051/aacus/2021009 and https://doi.org/10.1051/aacus/2021008).

[6] The ideal string has a linear restoring force. More realistically, the restoring force has some non-linearity which increases the frequency at higher amplitude. So, as the amplitude decays, the pitch goes down. Inherent string stiffness makes this a bigger deal at higher frequency (i.e., shorter wavelength).

[7] This is a simplified version of the melody of *The Banjo Song* by the Brother Brothers, twin singer-song writers — https://www.youtube.com/watch?v=ws3wbU63nLQ and https://www.thebrotherbrothersmusic.com/.